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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND SYSTEM FOR DETECTION OF OBJECTS

(57) Abstract: A method for detection of an object, the method including irradiating a target with two electromagnetic wave energy beams, a first beam at a first frequency and a second beam at a second frequency, the first frequency being lower than the second frequency, both beams being polarized in a first direction, and determining a presence of an object by analyzing reflections of the first and second beams, wherein if there is a dominant reflection polarization in the first direction for both the first and second frequencies, then the target is considered not to have the object, and if there is a dominant reflection polarization in the first direction for only one of the first and second frequencies and a depolarized reflection at the other of the first and second frequencies, then the target is considered to have the object.

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METHOD AND SYSTEM FOR DETECTION OF OBJECTS

FIELD OF THE INVENTION

The present invention relates generally to the remote (non-contact) detection of objects, and particularly to the remote detection of persons carrying concealed metal objects, such as but not limited to, small metallic objects embedded in garments.

BACKGROUND OF THE INVENTION

For security reasons, it is frequently required to search a person, prior to entering a densely populated area (restaurants, malls, etc.), for the presence of concealed weapons or other means necessary for conduction of acts of violence. Such weapons are generally metallic or contain metallic components.

This kind of threat must be detected at a distance, since conventional metal detection systems (a gate or a hand-held metal detector), or a personal body search, necessitate the near proximity of the security personnel to the suspected person, and thus dangerously expose the personnel to this form of violence.

Prior art methods and systems for the remote detection of such threats include high-resolution radar systems capable of penetrating clothes covering the metallic objects. These systems, however, need a trained observer to monitor the obtained picture.

Passive radio wave systems have also been proposed, which pick up the RF region of the blackbody radiation emitted by the suspected person. These systems, however, employ detectors that require extreme cooling and are very expensive. In addition, again, a trained operator must monitor the display of the system. The detection range of these devices is rather limited.

SUMMARY OF THE INVENTION

The present invention seeks to provide a system and method for effectively detecting persons carrying concealed metallic objects. One embodiment includes a short-range radar system functioning at two frequencies, a first frequency which is relatively low (e.g., about 1 GHz) and a second frequency which is relatively high (e.g., a few GHz). The polarizations of the reflected frequencies are different depending on whether the person is carrying metallic objects or not, as is described hereinbelow. Comparing the dominant polarizations of the reflected high frequencies from a suspected individual as opposed to those from a control person not carrying any metallic objects may enable identification of a carrier of metallic objects.

The present invention is much cheaper than the prior art, incorporates an automatic physical discrimination, and has a much longer effective detection range.

There is thus provided in accordance with an embodiment of the present invention a method and a system for detection of an object, including an irradiation device capable of irradiating a target with two electromagnetic wave energy beams, a first beam at a first frequency and a second beam at a second frequency, the first frequency being lower than the second frequency, both beams being polarized in a first direction (such as but not limited to, the vertical direction with respect to the ground), and a processor capable of determining a presence of an object in the target by analyzing reflections of the first and second beams and comparing the reflections with reflections obtained from a control volume known to have the object therein, wherein the target is considered to have the object if the polarization characteristics of the reflections of the first and second frequencies match the reflections obtained from the control volume within a predefined tolerance.

In accordance with an embodiment of the present invention if there is a dominant reflection polarization in the first direction for both the first and second frequencies, then the target is considered not to have the object, and if there is a dominant reflection polarization in the first direction for only one of the first and second frequencies (for example, the first, lower frequency) and a depolarized reflection at the other of the first and second frequencies (for example, the second, higher frequency), then the target is considered to have the object.

The first and second frequencies may be, without limitation, in the range 100 kHz-18 GHz. For example, the first frequency may be less than about 1.5 GHz, and the second frequency may be greater than about 1.5 GHz. As another example, the first frequency may be less than or equal to approximately 1 GHz, and the second frequency may be equal to or greater than approximately 2 GHz.

In accordance with an embodiment of the present invention an alarm may be triggered if the target is considered to have the object.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Electromagnetic waves in the radio frequency (RF) range are reflected by electrically conducting bodies. The intensity of reflection is dependent on various factors, such as but not limited to, the type of charge carrier (electrons or dissolved ions), the wave frequency (as the electrical properties of the material depend on the electric field frequency) and the size of the conducting body in relation to the wavelength, for example.

The dominant mode of electric conduction in biological tissue is by ionic motion. The efficiency of conduction by ionic motion is limited to frequencies up to ~1GHz. In

contrast, electron conductivity has no such limit in the RF region. The difference may be due to the large mass differences between ions and electrons.

Conducting bodies reflect stronger when their size is comparable to the wavelength, peaking at about $L=\lambda/2$, where L is the body dimension parallel to the polarization of the electric component of the wave, and λ is the wavelength.

Conducting bodies that have a long dimension comparable in size to the wavelength, while their short dimension is significantly smaller, reflect as follows:

a. If the body is positioned such that the long dimension is parallel to the wave polarization, then the body reflects the wave and retains the original polarization.

b. If the body is positioned such that the long dimension is neither parallel nor perpendicular to the wave polarization, then the body reflects the wave but the reflection loses its original polarization.

c. If the body is much larger than the wavelength (both in width and length), then the body reflects the wave well and retains the original polarization.

In the case of a person carrying or wearing a suicide bomb, one of the reflecting bodies is the person carrying the bomb. Biological tissue conducts mainly by induction of translational motion of the ions dissolved in tissue water. The long axis of the person is in most cases vertical (walking or standing), and thus frequencies up to ~1 GHz may be best reflected when vertically polarized. The reflection may also have a strong vertical polarization.

Other reflecting bodies are the metallic objects (e.g., a few cm long and a few mm wide) embedded in the explosive material. These reflect well at shorter wavelengths, but due to their random orientation in the explosive, produce a relatively non-polarized reflection for wavelengths of the same approximate size as that of the objects (that is, relatively high frequencies).

In the present invention, the suspected person may be irradiated by vertically polarized RF beams at a first (relatively low) frequency (e.g., less than or equal to ~1GHz) and at a second (higher than the first) frequency (e.g., 2-3 GHz and above). If a person is not carrying an assortment of metallic objects, then there will be a dominant vertical reflection polarization for both the first and second frequencies. In contrast, if the person is carrying an assortment of metallic objects, then there will be a dominant low frequency vertical reflection polarization, while at high frequencies the reflected wave will be depolarized. Comparing the dominant polarizations of the low and high frequencies of the reflected waves may thus enable identification of a carrier of metallic

objects. A reflected pattern, which complies with the above description of the reflected pattern of a person carrying assorted metallic objects, may be used to trigger an alarm. The alarm may include, without limitation, a visual and/or audible signal, a palpitating alarm, or anything else that attracts the attention of a person monitoring the system.

The spatial position of the suspected person may be obtained routinely from the radar acquired data (or from some other source, such as but not limited to, GPS), as is well known in the art of radar.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of the features described hereinabove as well as modifications and variations thereof which would occur to a person of skill in the art upon reading the foregoing description and which are not in the prior art.

CLAIMS

What is claimed is:

1. A method for detection of an object, the method comprising:

irradiating a target with two electromagnetic wave energy beams, a first beam at a first frequency and a second beam at a second frequency, the first frequency being lower than the second frequency, both beams being polarized in a first direction; and

determining a presence of an object by analyzing reflections of said first and second beams, wherein:

if there is a dominant reflection polarization in said first direction for both the first and second frequencies, then the target is considered not to have the object, and

if there is a dominant reflection polarization in said first direction for only one of the first and second frequencies and a depolarized reflection at the other of the first and second frequencies, then the target is considered to have the object.

2. The method according to claim 1, wherein if there is a dominant reflection polarization in said first direction for the first frequency and a depolarized reflection at the second frequency, then the target is considered to have the object.

3. The method according to claim 1 or claim 2, wherein said first beam and second beams are polarized in the vertical direction with respect to the ground.

4. The method according to any of the preceding claims 1-3, wherein the first and second frequencies are in the range 100 kHz-18 GHz.

5. The method according to any of the preceding claims 1-3, wherein said first frequency is less than about 1.5 GHz, and said second frequency is greater than about 1.5 GHz.

6. The method according to any of the preceding claims 1-3, wherein said first frequency is less than or equal to approximately 1 GHz.

7. The method according to any of the preceding claims 1-3, wherein said second frequency is equal to or greater than approximately 2 GHz.

8. The method according to any of the preceding claims, further comprising triggering an alarm if said target is considered to have the object.

9. The method according to any of the preceding claims, further comprising sensing a spatial position of the target.

10. A system for detection of an object comprising:

an irradiation device capable of irradiating a target with two electromagnetic wave energy beams, a first beam at a first frequency and a second beam at a second frequency,

the first frequency being lower than the second frequency, both beams being polarized in a first direction; and

a processor capable of determining a presence of an object in the target by analyzing reflections of said first and second beams and comparing the reflections with reflections obtained from a control volume known to have the object therein, wherein the target is considered to have the object if the polarization characteristics of the reflections of the first and second frequencies match the reflections obtained from the control volume within a predefined tolerance.

11. The system according to claim 10, wherein the processor is capable of determining the presence of the object in the target by analyzing reflections of said first and second beams, wherein:

if there is a dominant reflection polarization in said first direction for both the first and second frequencies, then the target is considered not to have the object, and

if there is a dominant reflection polarization in said first direction for only one of the first and second frequencies and a depolarized reflection at the other of the first and second frequencies, then the target is considered to have the object.

12. The system according to claim 11, wherein if there is a dominant reflection polarization in said first direction for the first frequency and a depolarized reflection at the second frequency, then the target is considered to have the object.

13. The system according to any of claims 10-12, wherein said first beam and second beams are polarized in the vertical direction with respect to the ground.

14. The system according to any of the preceding claims 10-13, wherein the first and second frequencies are in the range 100 kHz-18 GHz.

15. The system according to any of the preceding claims 10-13, wherein said first frequency is less than about 1.5 GHz, and said second frequency is greater than about 1.5 GHz.

16. The system according to any of the preceding claims 10-13, wherein said first frequency is less than or equal to approximately 1 GHz.

17. The system according to any of the preceding claims 10-13, wherein said second frequency is equal to or greater than approximately 2 GHz.

18. The system according to any of the preceding claims 10-17, further comprising an alarm in communication with said processor, wherein said alarm is triggered if said target is considered to have the object.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL2004/000891

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01V3/12 G01V8/00 G01S13/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01V G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/034444 A1 (CHADWICK GEORGE G ET AL) 20 February 2003 (2003-02-20) paragraphs '0002!, '0743!, '0060!, '0061!, '0085!, '0086!	1,10
A	US 5 177 445 A (CROSS THOMAS E) 5 January 1993 (1993-01-05) column 1, line 5 - line 54; claim 1	1,10
A	EP 1 338 902 A (QINETIQ LTD) 27 August 2003 (2003-08-27) paragraphs '0002!, '0009!, '0019!, '0033!, '0045!, '0148!, '0158!	1,10
A	US 6 359 582 B1 (MACALEESE GREGORY B ET AL) 19 March 2002 (2002-03-19) column 1, line 15 - line 16; claim 1	1,10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 January 2005	25/01/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Lorne, B

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IL2004/000891

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003034444 A1	20-02-2003	US 6342696 B1	29-01-2002
		AU 7569900 A	28-12-2000
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		WO 0075892 A2	14-12-2000
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		IL 128973 A	10-04-2003
		JP 2002514298 T	14-05-2002
		KR 2000036249 A	26-06-2000
		WO 9812573 A1	26-03-1998

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

3\|3

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY
(PCT Rule 43*bis*.1)

	Date of mailing *(day/month/year)* see form PCT/ISA/210 (second sheet)
Applicant's or agent's file reference see form PCT/ISA/220	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IL2004/000891	23.09.2004	24.09.2003

International Patent Classification (IPC) or both national classification and IPC
G01V3/12, G01V8/00, G01S13/04

Applicant
SOREQ NUCLEAR RESEARCH CENTER

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA"). However, this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of three months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IL2004/000891

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This opinion has been established on the basis of a translation from the original language into the following language , which is the language of a translation furnished for the purposes of international search (under Rules 12.3 and 23.1(b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ in written format

   ☐ in computer readable form

   c. time of filing/furnishing:

   ☐ contained in the international application as filed.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-18
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-18
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-18
	No:	Claims	

2. Citations and explanations

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following document :

D1: US 2003/034444 A1 (CHADWICK GEORGE G ET AL) 20 February 2003 (2003-02-20)

2. The document D1 is regarded as being the closest prior art to the subject-matter of claim 1, and discloses (the references in parentheses applying to this document) a method for detection of an object comprising the following steps of :
-illuminating a target with horizontally polarized radio waves;
-collecting first radiation reflected from said target which has a polarization which is the same as the radiation used to illuminate said target;
-collecting second radiation reflected from said target which is oppositely polarized to that of said radiation which is used to illuminate said target.

The subject-matter of claim 1 differs from this known document in that a target is irradiated with two electromagnetic wave energy beams polarized in the same direction but with two different frequencies.

The subject-matter of claim 1 is therefore new (Article 33(2) PCT).

3. The problem to be solved by the present invention may be regarded as a desire to improve a method for the detection of an object which has an automatic physical discrimination and a longer effective detection range.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) since none of the document cited in the search report (alone or in combination with another) disclose or suggest the comparison of dominant reflection polarization directions between two reflected electromagnetic wave

energy beams having different frequencies.

4. For the same reasons, the subject matter of the corresponding apparatus claim 10 is new and involves an inventive step (Article 33(2)(3) PCT)

5. Claims 2-9 and 11-18 are dependent on claims 1 and 10 and as such also meet the requirements of the PCT with respect to novelty and inventive step.